CLAIMS

1. A method for producing carbon nanowalls comprising the steps of creating a plasma atmosphere in at least one region of a reaction chamber by plasmatizing a source material containing carbon, introducing radicals generated outside the plasma atmosphere into the plasma atmosphere, and growing carbon nanowalls on a base material disposed in the reaction chamber.

2. The method according to Claim 1, wherein the radicals are generated by decomposing a radical source outside the reaction chamber.

3. The method according to Claim 2, wherein the radicals are generated by applying microwaves, UHF waves, VHF waves, or RF waves to the radical source and/or bringing the radical source in contact with a hot metal catalyst.

4. The method according to any one of Claims 1 to 3, wherein the radicals include hydrogen radicals.

5. The method according to any one of Claims 1 to 3, wherein hydrogen radicals are generated by decomposing a radical source containing hydrogen and then introduced into the plasma atmosphere.

6. The method according to any one of Claims 1 to 5, wherein the source material contains carbon and hydrogen.

7. The method according to any one of Claims 1 to 5,

wherein the source material contains carbon and fluorine.

8. The method according to any one of Claims 1 to 7, wherein at least one of the feed rate of the source material, the plasmatization degree of the source material, and the feed rate of the radicals is controlled on the basis of the concentration of carbon radicals, hydrogen radicals, or fluorine radicals in the reaction chamber.

9. An apparatus for producing carbon nanowalls grown on a base material, comprising a reaction chamber to which a source material containing carbon is fed and in which the base material is disposed, a plasma discharger for plasmatizing the source material in the reaction chamber, a radical-generating chamber to which a radical source is fed, and a radical generator for generating radicals from the radical source in the radical-generating chamber, wherein the radicals generated by the radical generator are introduced into the reaction chamber.

10. The apparatus according to Claim 9, wherein the radical generator has at least one of a function of applying microwaves, UHF waves, VHF waves, or RF waves to the radical-generating chamber and a function of heating a metal catalyst opposed to the radical-generating chamber.

11. The apparatus according to Claim 9 or 10, wherein the radical generator is configured such that the radicals are fed to the reaction chamber through a radical-introducing

port that open on a face of the base material on which the carbon nanowalls are formed.

12. The apparatus according to any one of Claims 9 to 11, further comprising a concentration-measuring unit for measuring the concentration of carbon radicals in the reaction chamber, wherein the concentration-measuring unit includes a light emitter for emitting an emission line characteristic of the radicals into the reaction chamber and a light detector for detecting the emission line emitted from the light emitter.

13. The apparatus according to any one of Claims 9 to 12, further comprising a concentration-measuring unit for measuring the concentration of hydrogen radicals in the reaction chamber, wherein the concentration-measuring unit includes a light emitter for emitting an emission line characteristic of the radicals into the reaction chamber and a light detector for detecting the emission line emitted from the light emitter.

14. The apparatus according to any one of Claims 9 to 13, further comprising a concentration-measuring unit for measuring the concentration of fluorine radicals in the reaction chamber, wherein the concentration-measuring unit includes a light emitter for emitting an emission line characteristic of the radicals into the reaction chamber and a light detector for detecting the emission line emitted

from the light emitter.

15. The apparatus according to any one of Claims 12 to 14, further comprising a control unit for controlling at least one of the feed rate of the source material, the plasmatization degree of the source material, the feed rate of the radicals, the feed rate of the radical source, and the radicalization degree of the radical source on the basis of the radical concentration determined with any one of the concentration-measuring units.

16. The apparatus according to any one of Claims 9 to 15, wherein the reaction chamber has a plurality of radical-introducing ports, spaced from each other, opposed to the face of the base material on which the carbon nanowalls are formed, the base material being disposed in the reaction chamber.

17. The method according to any one of Claims 1 to 8, wherein the base material has no metal catalyst disposed thereon.

18. The method according to any one of Claims 1 to 5, wherein the source material contains at least one of carbon, hydrogen, and fluorine that are essential components.

19. The method according to Claim 6, wherein the source material is CH_4.

20. The method according to Claim 7, wherein the source material is at least one of C_2F_6 and CF_4.

21. The method according to Claim 18, wherein the source material is CHF_3.

22. The method according to any one of Claims 1 to 5, wherein the source material is selected from a gas containing carbon and hydrogen; a gas containing carbon and fluorine; and a gas containing carbon, fluorine, and hydrogen and at least two of the gases are alternately switched in any one of the steps.

23. The method according to any one of Claims 1 to 8 and 17 to 22, wherein the introduced radicals include no OH radicals.

24. The method according to any one of Claims 1 to 8 and 17 to 23, wherein the amount of the introduced radicals in the region is measured and at least one of the feed rate of the source material and the feed rate of the radicals is controlled on the basis of the radical amount.

25. The method according to any one of Claims 1 to 8, wherein properties of the carbon nanowalls are varied by varying the ratio of the feed rate of a source material containing carbon and fluorine and that of another material containing carbon and hydrogen.

26. The method according to any one of Claims 1 to 8 and 17 to 25, wherein the carbon nanowalls are oriented by tilting a line normal to the base material with respect to the direction of a electric field.

27. The method according to any one of Claims 1 to 8 and 17 to 26, further comprising the step of pretreating the base material by applying the radicals to the base material without plasmatizing the source material before the growth of the carbon nanowalls.

28. A carbon nanowall comprising two-dimensional carbon nanostructures containing no metal catalyst.

29. The carbon nanowall according to Claim 28, wherein the carbon nanostructures are wall-shaped and extend from a base material.

30. The carbon nanowall according to Claim 29, wherein the carbon nanostructures are longitudinally oriented in a single direction.

31. The apparatus according to any one of Claims 9 to 16, further comprising a shield member which is grounded, which is disposed between the reaction chamber and the radical-generating chamber, and which has a large number of perforations through which the radicals pass.

32. The apparatus according to any one of Claims 9 to 16, wherein the radical-generating chamber is located above or below the reaction chamber and the radicals are applied to the growth face of the base material disposed in the reaction chamber.

33. The apparatus according to Claim 32, wherein the plasma discharger includes a first electrode for applying a

high-frequency electric power and a second electrode which is opposed to the first electrode, which is parallel to the first electrode, and on which the base material is set, the first electrode has a large number of perforations, and the radicals are converted from ions by the collision of particles generated in the radical-generating chamber with the walls of the perforations and then introduced into the reaction chamber.

34. The apparatus according to Claim 33, wherein the source material is fed to the reaction chamber through the perforations of the first electrode.

35. A parallel plate-type plasma-processing apparatus comprising a first electrode, having a large number of perforations, for applying an electric power; a second electrode which is opposed to the first electrode, which is parallel to the first electrode, and on which a workpiece is set; a reaction region to which gas is fed, which is located between the first and second electrodes, and in which a plasma is generated; a high-frequency power supply for applying high-frequency waves to a region between the first and second electrodes to plasmatize the gas; a radical-generating region which is spaced from the second electrode with the first electrode disposed therebetween and to which a radical source is fed; a radical generator for generating radicals from the radical source in the radical-generating

region; a shield member which is disposed between the first electrode and the radical-generating region, which partitions the radical-generating region, which has a large number of perforations that are aligned with the perforations of the first electrode such that the radicals pass through these perforations, and which is grounded, wherein the radicals generated by the radical generator are introduced into the reaction region through the perforations of the shield member and the perforations of the first electrode.

36. The plasma-processing apparatus according to Claim 35, wherein the radical generator serves as a microhollow plasma generator and includes a pair of an inside electrode and an outside electrode, the inside and outside electrodes are spaced from each other and have a large number of microhollows which are aligned with each other and in which plasmas are generated, the inside electrode serves as a cathode, and the outside electrode is located close to the reaction region and grounded so as to serve as well as the shield member.

37. The plasma-processing apparatus according to Claim 35 or 36, wherein the gas fed to the reaction chamber is fed to the reaction region through the perforations of the first electrode.